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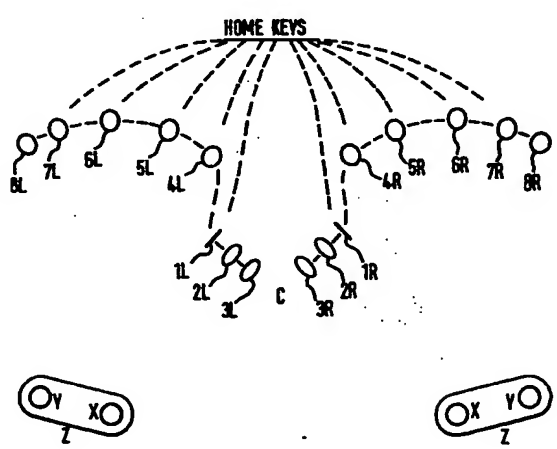
⑤④ **Keyboard.**

⑤⑦ A keyboard for a typewriter or a computer comprises two groups of keys for operation by the digits of the two hands of an operator. Each group has five home keys, and possibly also some non-home keys, arranged in a single continuous row. A decoder is provided for decoding the operation of the keys so that operation of each individual home key of the first group signals a respective vowel and simultaneous operation of a home key of the first group and a home key of the second group signals a consonant.



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IMPROVEMENTS IN OR RELATING TO KEYBOARDS

The present invention relates to keyboards. Such keyboards may be used with any machines for communicating, storing, processing or retrieving representations of information, such as telegraphs, typewriters, type composing machines, cyphering machines, calculators and computers. Such a keyboard is particularly suitable for use with modern types of computer having visual display units and full screen editing facilities. Such computers are being increasingly used by originators of information without the intervention of specialist keyboard operators.

According to the invention, there is provided a keyboard, comprising a plurality of keys arranged in first and second groups for operation by the digits of respective hands of an operator, and means for decoding operation of the keys to provide signals representative of characters, characterised in that each group of keys comprises or includes five home keys arranged in a first single continuous row for respective digits of the hand, and in that the decoding means is arranged to produce a signal representative of each of the vowels upon operation of a respectiv single home key of the first

group and t produce a signal r presentative of each of at least some of the consonants upon simultaneous operation of a home key of the first group and a home key of the second group.

Preferably, the decoding means is arranged to produce a signal representative of at least some of the consonants upon simultaneous operation of the home key of the first group corresponding to the vowel preceding the respective consonant in alphabetical order and a home key of the second group.

Preferably, the first and second groups of keys are arranged to be operated by the left and right hands, respectively.

Preferably, the home keys of the first group corresponding to the vowels <u>a</u>, <u>e</u>, <u>i</u>, <u>o</u> and <u>u</u> are arranged to be operated by the thumb and the index, middle, ring, and little finger, respectively. Preferably, the decoding means is arranged to provide signals representing five common consonants or other characters (including space) upon operation of respective single home keys of the second group. Preferably, the decoding means is arranged to produce a signal representative of each of the remaining consonants upon simultaneous operation of the k y of the

first gr up c rr sponding t th alphabetically preceding vowel and the respective home key of the second group corresponding to the relative position of the consonant with respect to the remaining consonants following the vowel and taken in order from the thumb to the little finger.

Preferably, the decoding means is arranged to produce a signal representative of an accented letter upon simultaneous operation of the key or keys for selecting the non-accented letter and a further key or keys.

Preferably, at least one of the groups of keys includes a non-home key for operation by the thumb, and the decoding means is arranged to produce a signal representative of a space in response to operation of the non-home thumb key. Preferably, the decoding means is arranged to produce signals representative of space repeatedly in response to simultaneous operation of the non-home thumb key and at least one finger key of the same group, the frequency of repetition depending on the finger key or keys operated.

Preferably, each of the first and second groups of keys includes a non-home key for operation by the thumb, and th d coding means is arranged to produce a signal r pres ntative of a space in response to simultaneous

peration of both the non-home thumb keys. Preferably, the decoding means is arranged to produce signals representative of space repeatedly in response to simultaneous operation of both the non-home thumb keys and of at least one finger key, the frequency of repetition depending on the finger key or keys operated.

Preferably, each of the first and second groups of keys includes a non-home key for operation by the little finger, and the decoding means is arranged to produce signals representative of a period (full stop) and comma in response to operation of the respective non-home little finger keys.

In one embodiment, the keyboard includes at least one shift key arranged to be operated by the heel of the hand and the decoding means is arranged to perform a shift function in response to operation of the shift key or keys. In another embodiment, the keyboard includes at least one shift key arranged to be operated by the heel of the hand and the decoding means is arranged to perform a shift function in response to release of the shift key or keys.

Preferably, the decoding means is arranged to produce a signal representative of a numeric digit in response to operation of a respectiv home key when in numeric

shift. Pr ferably, the decoding m ans is arrang d to produce a signal representative of zero upon operation of a non-home thumb key disposed adjacent to a home thumb key. Preferably, the decoding means is arranged to produce multiple signals representative of zero upon simultaneous operation of the non-home thumb key and at least one finger key of the same group, the number of zeroes produced depending on the finger key or keys operated.

Preferably, the decoding means is arranged to produce signals representative of cursor movement in response to operation of a home thumb key or an adjacent non-home thumb key when in control shift, the thumb keys of one hand signalling horizontal movement and the thumb keys of the other hand signalling vertical movement. Preferably, the decoding means is arranged to produce signals representative of cursor movement repeatedly in response to simultaneous operation of a thumb key and at least one finger key of the same group, the frequency of repetition depending on the finger key or keys pressed. Preferably, the decoding means is arranged to produce signals representative of cursor movement at an angle in response to simultaneous operation of one home thumb key or adjacent non-home thumb key of each group when in control shift, the thumb key operated in one group determining the direction of the horizontal compon nt of

th m v ment and the thumb key operated in the other group determining the direction of the vertical component of the movement.

Preferably, the decoding means is arranged to produce signals representative of cursor movement at an angle repeatedly in response to the simultaneous operation of a thumb key of each group and at least one finger key of each group, the thumb key and finger key or keys operated in one group determining the direction and speed, respectively, of the horizontal component of the movement and the thumb and finger key or keys operated in the other group determining the direction and speed, respectively, of the vertical component of the movement. Preferably, the decoding means is arranged to produce a signal representative of the 'Run' function in response to the simultaneous operation of a further non-home thumb key of each group when in the control shift, the further non-home thumb keys being disposed at the ends of the rows of keys in each group remote from the home thumb keys for operation by the extended thumbs.

Preferably, the keyboard is shaped to fit the natural curve of the hands at rest with the fingers curved in a moderate arc and the wrists straight. Preferably, the general planes of the keys for each hand are tilted outwards in ord r to r duc the angle of forearm

pronati n. Pref rably, the or at l ast n thumb key f each group is disposed at an angle to the general plane of the finger keys of the respective group for operation by adduction of the thumb towards the palm of the hand. Preferably the home thumb key of each group is disposed substantially at right angles to the general plane of the finger keys of the respective group and non-home thumb keys of each group are disposed substantially parallel to the respective general plane, so that the home and adjacent non-home thumb keys may be operated from the same position of the thumb.

In one embodiment, each group of keys includes five additional keys arranged in a second single continuous row for operation by respective digits of the respective hand, and the decoding means is arranged to produce in response to operation of at least one key of the first and second rows, including at least one key of the second row, a signal representative of the same characters as in response to corresponding keys all of the first row, preceded or followed by a signal representative of the space character. In another embodiment, each group of keys includes at least one elongated key arranged to be operated by any of a plurality of digits of the respective hand, and the decoding means is arranged to produce, in response to simultan ous operation of at least one key in the first

rows of k ys and at l ast one of th elongated keys, a signal representative of the same character as in response to operation of the at least one key of the first rows only preceded or followed by a signal representative of the space character. In a further embodiment, each of at least the home keys of each group is provided with an additional distinct motion, and the decoding means is arranged to produce, in response to the additional distinct motion of at least one of the home keys, a signal representative of the same character as in response to operation of the same key combination without the additional motion preceded or followed by a signal representative of the space character.

It is thus possible to provide a keyboard which is easy to use and such that information originators can begin using a keyboard with a minimum of formal instruction, practical work develops their skill without any need for formal skill building training, occasional users can on each occasion of use quickly recover their former level of skill and users at any skill level experience minimal sense of fatigue. Experienced users can attain performance levels comparable with those of trained information originators using conventional keyboards.

It is also possible to provid a standard k yboard which

can b effici ntly us d by a native speak r of any language written with the Latin alphabet to key his own or any other language of the group. It is further possible to provide an efficient keyboard for all character processing work including cursor movement and other machine control functions, so that auxiliary devices such as a mouse or puck are only required for graphics processing.

It is possible to reduce the size and weight of keyboards in order to improve portability and occupy less of the user's working surface, to reduce or eliminate the noise made by conventional keyboards, and to reduce manufacturing costs. It is also hoped that by increasing the proportion of information entered into machines by its originators, and decreasing the need for specialist keyboard operators, the invention may contribute towards the social objective of equality between all men and women.

In general terms any system for the communication of representations of information from the human brain to the internals of a machine must comprise a part of the brain engaged upon encoding the information representation into impulses acceptable to the machine, the nervous sytem, musculature and other anatomical features required to d liver the impulses to the

machine, th parts of the machine formed to receive the impulses, and the parts of the machine which determine that a valid impulse or combination of impulses has been received and transform it into the form used in the internals of the machine. In the present case, the impulses are delivered by the hands to a keyboard and may be transformed into any internal code such as the ISO 7-bit coded character set for information processing interchange, or directly into the operations of an output mechanism as in a typewriter.

Modern learning theory stresses the importance of providing the mind of a machine operator with a coherant, easily remembered mental model of the workings of the machine, around which to build his detailed understanding and effective performance. A primary design objective of the machine is therefore to promote this mental model in the mind of the user, so that the outcome will be ease of use.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic plan view of a keyboard constituting a preferred embodiment of the invention;

Figur 2 shows diagrammatically a lateral cross-section of the keyboard of Figure 1;

Figures 3 and 4 illustrate another embodiment of the keyboard;

Figures 5 to 21 illustrate in matrix form operation of keys of the keyboard for signalling characters and control functions;

Figures 22 and 23 illustrate two further embodiments of the keyboard;

Figure 24 is a block schematic diagram of the keyboard decoding means; and

Figures 25 to 28 show a flow chart illustrating operation of the decoder.

Figures 1 and 2 show a keyboard, constituting a preferred embodiment of the invention, having eighteen keys and shaped to fit the natural shape of the hands at rest with the arms converging on the keyboard and the wrists straight. Working outwards from the centre C of the keyboard, the first three keys on each side are intended to be operated by th thumbs, which hav the greatest mobility of all th digits. Th outermost key

1L, 1R of each group is placed substantially at right angles to the others of the group, so that the thumb may operate it or the middle thumb key 2L, 2R from the same initial position without loss of time, and so that the work is divided between two different muscle groups. In an efficient distribution of the required characters and machine functions across the keys, the innermost thumb key 3L, 3R of each hand will be more lightly loaded than the two outer keys 1L, 1R, 2L, 2R. The remaining digit keys resume the general orientation of the inner thumb keys 2L, 2R, 3L, 3R.

Continuing outwards from the thumb keys, the next three keys 4L, 5L, 6L, 4R, 5R, 6R on each side are intended to be operated by the index, middle, and ring fingers. These fingers have little lateral mobility and so operate only one key each. They will locate the hands at all times. The hands make no movements as a whole, and thus the problem of reaches is eliminated. The outermost two keys 7L, 8L, 7R, 8R on each side are intended to be operated by the little fingers, which have some lateral mobility. In accordance with ordinary typewriter usage, the five adjacent thumb and finger keys 1L, 4L, 5L, 6L, 7L, 1R, 4R, 5R, 6R, 7R of each hand operated by the unextended hand will be termed the "home" keys. Figure 1 identifies these keys. In other mbodiments of the inv ntion, ther may b a different

number of digit keys, and some or all of the thumb keys may be substantially parallel to the finger keys, at right angles to them, or opposed to them at 180 degrees. The general planes of the finger keys for the two hands may be tilted outwards to reduce forearm pronation at any angle from zero degrees to substantially 90 degrees.

The thumb and finger keys are used to signal characters and machine functions. They may be used in any combination, including simultaneous use of the two little fingers. With QWERTY and similar keyboards, one or other little finger is always available to press a shift key, with the proposed keyboard other arrangements must be made. Shift locks in the encoding scheme are not adequate alone, requiring three keystrokes to signal a single capital letter preceded and followed by lower case letters. The preferred keyboard is therefore provided with two keys placed for operation by the heels of the hands. Figure 1 shows these keys placed either for operation by the thenar eminences at at X, or for operation by the hypothenar eminences as at Y, or extending over the whole area of the heel of the hand as at Z. These keys are used as shift keys, and lights may be provided on the keyboard to indicate that the shifts are in effect, as is done with conventional keyboards. The shifts may b arranged as with conventional

keyboards so that the unshifted condition with no shift key pressed gives the lower case alphabet. Alternatively the keyboard may be arranged so that the lower case alphabet is obtained with both shift keys pressed and the user may rest the heels of his hands on the keyboard for most of the time to relieve the weight of the arms as when handwriting. A hardware or software switch may be provided to reverse the action of the shift keys, enabling the user to rest the heels of his hands on the keyboard for most of the time or not as he pleases. Shift locks may be provided in the encoding scheme so that the user need only make momentary departures from his preferred way of holding his hands.

Figs 3 and 4 show another preferred keyboard in which the spatial relationships between the left hand keys and the spatial relationships between the right hand keys remain as before, but the general planes of the hands are rotated outwards for the greater comfort of the wrists. Similar keyboards may be constructed with the general planes of the hands at any angle from substantially horizontal to substantially vertical. The keyboard may be divided into left and right hand portions separately locateable on the user's working surface so that his arms may remain parallel. Keyboards with greater or lesser number of keys may take the same general form. K yboards constructed as d scribed above

will be approximat ly half the size of c nventional computer keyboards and contain one-fifth the number of keys, thus reducing manufacturing costs. The keys may be of the type making a distinct mechanical movement as used in conventional quality keyboards, or of any known alternative type such as a flexible membrane effecting electrical contacts, piezo-electric cells, means of detecting the surface conductivity or the capacitance of the hand, photocells occluded by the hand, and so on. In the absence of large reaches, means requiring but slight force and displacement may be preferred. Keyboards of the above described types might be manufactured in a range of sizes for different hands, as are gloves. A person might have his own familiar keyboard, which he plugged into whichever machine he was using. Personal keyboards might be made of fine wood or other substances desired by individuals or matching particular environments, thus enhancing their acceptability. Keyboards may be built into other objects, for example a keyboard divided into left and right hand portions may be built into the arms of a chair so that a desk becomes unnecessary.

In what follows, the term key press refers to the act of pressing a single key. The term key stroke refers to the act of pressing and subsequently releasing a single fing r or thumb key or a group of such keys constituting

a chord k ystroke. A keystroke xtends in time from th moment the first key is pressed to the moment the last key is released. It is the interval of time between two successive null states of the keyboard with no finger or thumb key pressed. The shift keys and shift locks must be operated so that the desired shift is in effect at the beginning of a keystroke.

A keyboard having eight keys for the fingers and thumbs of each hand and two keys for the heels of the hands is capable of registering 2 to the power 18 or 262,144 distinct states. Only a small proportion of these states are required to represent the usual character sets. The minimisation of the physical effort of operating the keyboard allows the valid states to be chosen with memorability as the primary consideration, and efficiency as a secondary though still important consideration. The familiar 80/20 rule may be applied, efficiency being served in the small proportion of the work where it really matters, and memorability being given full weight in the remaining large proportion of the work.

The valid keystrokes of the invention are:

1. Any single finger or thumb key.

2. Any combination of one finger or thumb key of the

left hand and one fing r or thumb key of the right hand.

3. Selected other combinations of two or more finger or thumb keys.

4. Any of the above with the addition of either or both of the heel keys.

The strokes with a single finger or thumb key and those with one finger or thumb key of each hand may be represented by an at-least-notional matrix. In Fig 5, the cell marked Z corresponds to the null state of the keyboard with no finger or thumb key pressed, the eight cells marked L to the pressing of a single finger or thumb key of the left hand, the eight cells marked R to the pressing of a single finger or thumb key of the right hand, and the remaining cells marked X to the pressing of one left hand finger or thumb key and one right hand finger or thumb key in combination. The five rows directly beneath the cell Z and the five columns directly to the right of the cell Z correspond to the home keys. Similar matrices may be drawn for keyboards having other numbers of finger and thumb keys. Any cell of a matrix could be assigned to the null state of the keyboard, but the assignment shown, with the above described relationship to the home keys, is preferred for keyboards us d with Latin alphabets. Clearly and

trivially, it would also b possible to represent the action of the keyboard by a matrix with axes reversed or by one tilted 45 degrees into a symmetric position. These however would be psychologically less effective with the proposed character assignment. The relationships between keyboard and matrix as defined above and with reference to Fig 5 are assumed in subsequent figures.

The two heel keys used as shift keys singly or in combination select one of four matrices or cases. The four matrices may contain the lower case alphabet, the upper case alphabet, numerics, and machine control functions. Additional cases may be provided within the machine and attached temporarily to a shift in place of the usual case. For example, a compositor may use italics in place of numerics, or a computer programmer the reserved words of a programming language in place of lower case.

The assignment of the alphabet in the upper and lower alphabetic cases is identical so that the same fingering is used in either case, as with conventional keyboards. Fig 6 shows one proposed assignment, having the five vowels AEIOU assigned to the home keys of the left hand, and the consonants to the key combinations which follow in s qu nce across the matrix. Letter A is obtained by

pr ssing the left hand hom thumb key. Letter B is obtained by pressing the left hand home thumb key as for letter A, together with the right hand home thumb key. Letter C is obtained by pressing the same left hand key together with the right hand index finger key, letter D similarly with the right hand middle finger key. Letter E is obtained by pressing the left hand index finger key. Letter F is obtained by pressing the left hand index finger key as for letter E together with the right hand home thumb key, and so on through to letter Z, obtained by pressing the left hand home little finger key as for letter U, together with the right hand home little finger key. This assignment gives a wholly consistant visual image in which the position of any letter in the matrix is easily seen. Alternatively, the encoding of any letter may be deduced logically. It is only necessary to remember that the vowels are obtained in alphabetic sequence by the left hand, and the consonants by selecting the preceding vowel in the alphabetic sequence with the left hand and then reciting the alphabet from that point on while marking across the right hand keys until the desired consonant is reached, or the next vowel if the starting vowel was wrongly chosen. The assignment of Fig 6 thus fully attains for the alphabetic characters the objective of providing a coherant, easily remembered mental model. The beginner will be conscious of both the matrix as a visual image

and th physical arrangement of the k yboard. With a little practice, the key press or combination of key presses required to indicate any cell of the matrix will become automatic and applicable to any of the cases. With further practice, the visual image in turn will largely recede from consciousness and the response to a desire to signal a certain letter or other common symbol become wholly automatic. The experienced user will key automatically for the most part, reverting to the level of the visual image only if automatic action fails, and to logical reasoning about the spatial relationships of symbols in the matrices only if he is not certain of the visual image. An important feature of the invention is that this reversion is possible, whereas with the QWERTY, Dvorak and like keyboards memory exists only at the psychokinetic level, and if this fails it is usually necessary to search the keyboard for the desired symbol because its largely random organisation does not facilitate visual memory.

Although the assignment of Fig 6 fully meets the objective of memorability, it is not particularly efficient when the relative frequencies of the letters of the alphabet are considered. The vowels amounting to some 38% of average English text require only one key press, but the consonants amounting to some 62% require two key press s. While the data in various sourc s

diff rs s m what according to the nature of the t xt samples used, all sources agree that the five consonants HNRST are the most frequently occurring, amounting to some 35% of average English text, and that the difference in frequency of occurrance between the least frequent of these five and the sixth most frequent consonant is significant. Fig 7 shows another assignment of letters to the alphabetic matrices in which H, N, R, S and T are assigned to the right hand home keys pressed alone. The remaining consonants are obtained by pressing one left hand and one right hand key as before. The English language has the useful property that the most frequently occurring consonants immediately precede vowels in the alphabetic sequence, so that the A, E, I, O and U rows of the matrix remain visually unbroken. With this assignment some 73% of the letters in average English text require only one key press. The arrangement is also fairly good with respect to the distribution of digrams, some 51% of consecutive letter pairs being given by consecutive single key presses of opposite hands. This measure is one of the most important with keyboards having one key for each character and machine function, because the large hand movements required must be overlapped for speed, but is less important with keyboards requiring only slight hand movements. In average text, the characters space, comma and period also occur with sufficient frequency for

effici ncy to be important. Space occurs more frequently than any single letter; comma and period rank about halfway down the letters. The remaining punctuation marks occur with insignificant frequency. In Fig 8, three cells of the matrix are allocated to the space character. Space may be signalled by the left hand thumb alone, the right hand thumb alone, or both together. There is no advantage in using both thumbs to signal a single space, but it may happen accidentally, and this allocation ensures that a correct signal will be given. Normally one thumb or the other will be used as convenient, dividing the work between them. More than half of English words end with D, E, S, or T, and more than half begin with A, O, S, T or W, so the proposed allocation of the letters leaves one or other thumb free to move in anticipation of the space. Repeated spaces may be obtained immediately, without the auto-repeat delay time of conventional computer keyboards, by pressing one thumb key and at least one finger key of the same hand, or both thumb keys and at least one finger key, the frequency of repetition and therefore the speed of movement across the screen depending on the finger key or keys pressed. When setting out text, a required string of spaces may be signalled rapidly at first, slowing as the required number of spaces or final position is reached. The keyboard simulat s the action of the hand drawing a

line, and slowing as the desired end point is r ach d. Comma and period are allocated to single key presses, requiring however a moment to extend a little finger. The extension of the little finger serves usefully to punctuate the rhythm of the work in accordance with the rhythm of the text, thus giving weight to its meaning. The remaining punctuation marks are allocated to combination presses of a little finger of one hand and a finger of the opposite hand. The punctuation marks as a whole form a memorable arrangement. The same punctuation marks in the same arrangement may be provided on the lower and upper alphabetic cases and on the numeric case for memorability and ease of use, whereas on the QWERTY keyboard only the comma and period are generally available in both shifts.

Fig 8 also shows a proposed allocation of two cells for the Auto-complete and Help functions if used. The Auto-complete function, when signalled instead of a normal space, completes the last word by reference to a stored dictionary, and inserts a space after it unless a punctuation mark follows. It is appropriate to locate this function near to the space character, and in the same position as the "Run" function in the control case described below. The "Help" function presents helpful information to a user who does not know what to do n xt. This function is appropriately located in a

psychol gically weak position r lated to the physical weakness of the little fingers and the spread hands gesture of helplessness. The auto-complete function may be provided on both alphabetic matrices, and the help function on all matrices.

Fig 8 further shows the letters HNRST, allocated to single key presses of the right hand, resequenced to balance across the right hand the work on letters, space and punctuation marks. These five letters are now in an apparently arbitrary sequence. However, as they are frequently occurring letters their positions will be quickly learnt. The bulk of the letter assignment including the infrequently used letters continues to be visually logical and deducible by reasoning.

Table 1 shows the total loading on the fingers and thumbs obtained by summing the percentage frequencies of the letters, space, and punctuation marks across the rows and columns of the matrix of Fig 8. The two motions of each thumb are counted separately and a reasonable distribution of space characters between the two thumbs is assumed. The grand total of 114 represents an average of 1.14 key presses per character, an increase of only 14% over the number of key presses required with a conventional keyboard, in return for which the reach s ar eliminated and so the force and

displac m nt required for each keypress can be much reduced. The work is evenly divided between the two hands, the right hand having 50.1% of the work. Corresponding fingers of the left and right hands are equally loaded. The right thumb has been given less work on its home key to free it for the majority of space characters. Table 2 compares this data, reduced now to a total of 100, with the digit loading of the QWERTY and Dvorak keyboards, and with data on finger strength and maximum tapping rate quoted in Alden et al (1972), also expressed on a base of 100. Space bar operations on the QWERTY and Dvorak keyboards have been assumed equally divided between the thumbs. The strength data quoted indifferently for a hand has been assumed to apply equally to the left and right hands. The keyboard of the present invention with the matrix of Fig 8 compares favourably with the QWERTY keyboard on the distribution of the work across the digits, and is comparable with the Dvorak keyboard, which was specifically designed to achieve an efficient distribution as well as minimising reaches. The data on strength supports the Dvorak design and the present invention, the data on speed suggests that an electric keyboard requiring but slight key force may safely make rather more use of the ring and little fingers if required. The matrix of Fig 8 allocates th five most frequent consonants to single key presses of the right

hand. If th user forgets that these letters d not follow in sequence in the vowel rows an error will occur. In another form of the invention shown in Fig 9, the matrix as implemented in the signal detection sub-system contains these consonants in both positions so that mistaken keyings will be accepted. In addition to its embodiment in the signal detection system, the matrix may have some embodiment visible to the user for training and reminder purposes. A computer program may display the matrix on part of the screen, highlighting the currently selected character for training purposes. A card may be supplied for reference. In such embodiments, the inefficient keyings of the five most frequent consonants would not be shown, and may be discouraged by blacking out those cells to strengthen the visual image as shown in Fig 10.

Fig 11 shows the visible form of the preferred matrix for the upper case. The layout of the letters is the same as in the lower case, as with conventional keyboards. A capitals shift lock function is provided at bottom left; keying this will alternately set and release the capitals shift lock within the signal detection system. Setting the capitals lock will release the numeric lock if set. With the capitals lock set, lower case is not available, upper case is availabl without actuating th upper cas shift key,

the numeric cas is obtained by actuating the numeric shift key in the same way as from lower case, and the control case is obtained by actuating both shift keys, in the same way as from lower case. The required actuation may as described previously be either to press or to release the shift key, depending on whether the user wishes to rest the heels of his hands on the keyboard for most of the time. Additional infrequently used punctuation marks, printer's marks or other special symbols associated with running text may be provided in the so far largely unused topmost row and leftmost column of an alphabetic matrix. Such symbols may be provided in the upper case matrix only, to leave room for accents in the lower case matrix.

From the previous description of alphabetic matrices for the English language, the general principles applicable to any language written with the Latin alphabet will be clear. The five vowels AEIOU are assigned to the left hand home keys in sequence, the remaining letters of the language are assigned to the vowel rows in alphabetic sequence, and the five most frequent consonants are also assigned to the right hand home keys, in the sequence which best balances the work of the right hand. With some languages, the suppression of the five most frequent consonants from the vowel rows of the visibl matrix corresponding to Fig 10 for the English language

will break into th se rows, w akening the visual image. To retain the strength of the visual image the five consonants placed on the top letter row may alternatively be selected only from the ends of the vowel rows at some slight sacrifice of efficiency. For users accustomed to working in two or more languages, matrices may include all the letters of the two or more languages in a combined alphabetic sequence, and the selection and sequencing of the five consonants of the top letter row may be based on combined frequency data. Matrices designed for use with one, two or more main languages and having the appropriate alphabetic sequence in the vowel rows and the appropriately selected and sequenced consonants assigned to the right hand home keys pressed alone may also be provided with additional letters in any convenient positions to enable their occasional use for keying other languages by persons not familiar with those languages. For example a matrix designed primarily for use with English, French and German may be provided with additional characters enabling its occasional use for Danish, Norwegian, Swedish and Icelandic. Table 3 shows selected frequency data for five European languages, taken from Einbinder (1973). Frequencies are expressed as a percentage of all letters and spaces, the punctuation marks and numerics amounting to 3% of average text being ignored. Th total fr qu ncy of all vowels diff rs betw en the

languages, and the mor liquid languages such as French, Spanish and Italian will load the left hand more heavily with the vowels. Comparing Italian with English, the vowel loading on the left hand increases by 7.6%, the top five consonants loading on the right hand decreases by 2%, the remaining consonant loading requiring chord keying by the left and right hands together decreases by 4.6%, and the space loading, divisible between the hands at will, decreases by 1%. The overall effect is a reduction in the work due to an increase in the proportion of characters signalled by a single key press. The effect on the fingers of the left hand is an increase of 3% only, the increase in the vowel loading being offset by the decrease in the chord consonant loading. The effect will be less for languages of intermediate liquidity. The varying percentages of individual vowels in the five languages when contrasted with the data of Table 2 do not suggest any particular difficulty, falling well within the limits of acceptability as evidenced by the QWERTY keyboard. Thus, keyboards constructed according to the invention are likely to prove suitable for any language written with the Latin alphabet.

Fig 12 shows a matrix with unspecified right hand home key consonants, and vowel rows appropriate to th major European languages, which is additionally provid d with

a compreh nsiv s t of accents and extra letters enabling it to be used for keying any European language written with the Latin alphabet. The accents may be keyed before or after the letters to which they apply, and the letter and its accent translated by the signal detection subsystem into any required internal computer code. In a typewriter or other machine which printed immediately, the accent would be keyed before its letter and would function as a 'dead' character, that is one which does not advance the printing position across the paper. Dipthongs may be signalled by keying the two vowels making up a dipthong simultaneously, the signal detection subsystem assuming a particular sequence of the components, for example OE. Single stroke accented letter encoding may additionally or alternatively be provided to increase speed. In these codes, the accented letter is represented by the key or keys which would be pressed to represent the unaccented letter, together with one or more additional keys. The adjacent thumb keys which operate substantially at right angles to one another are preferably not used together because special key mechanism would be required to secure reliable action, and it is also not desirable to extend a little finger when the middle or ring fingers of the same hand are to be used. The encoding is preferably provided only for the main language or languag s of the k yboard so that a simple cod can be

used. Accents for ign to th main language or languag s of the keyboard may be signalled by a separate keystroke as before. Fig 13 shows an accent coding scheme for the French language. The columns correspond to the right hand keys. The basic vowel symbol is keyed with the left hand, and the accent overcoded with the right hand, the same code being used for a given accent on all vowels. The right thumb may be thought of as 'holding' the vowel, so that the right finger does not indicate a consonant as it would if it alone were used with the vowel key. The accented C is keyed with the left thumb and right index finger as for the unaccented C, together with the right middle finger to signify the accent. Similar codes may be devised for any European language or group of languages.

In the numeric case, the ten digits of arithmetic are preferably assigned to the ten digits of the human hand as single key presses. Various arrangements are possible, and some of them are shown in Table 4. I is the sequence of the numeric keys in the cnventional QWERTY keyboard. The placement of 0 after 9 reflects the use of zero as a place value after other digits, and the fact that leading zeros are not generally required in running text. II has the mathematically more logical arrangement. Studies of the ten-key pads used on calculators and telephones have shown that it is b tter

to place 0 near 1, at least on r ctangular key arrays. Both I and II have the disadvantage that figure 0 is given to a little finger. 0 occurs much more frequently than the other digits, indeed mechanical calculating machines were often provided with keys for indicating 00 and 000. The arrangement III of the Dvorak keyboard overcomes this problem at the cost of a less obvious distribution of the digits. Marsan proposed arrangement IV, having observed that untutored children counting on their digits invariably begin with a thumb representing 1, generally the right thumb, proceed from there across the chosen hand, and then on to the other hand, beginning with the thumb taking value 6. His scheme again allocates 0 to a little finger. Scheme V allocates 0 to a thumb, and is mathematically more correct. Extensive experimentation would be required to determine the best of these arrangements.

Fig 14 shows a proposed numeric case having the numbers arranged as in scheme V of Table 4. Any other arrangement may be used. The punctuation marks are provided in the same positions as in the alphabetic cases since many of them are used with numbers or numeric codes. The usual arithmetic and logical operators, brackets and other symbols associated with numbers and calculations are provided in a memorable arrang ment. The ⌑ symbol r pres nts any desired

currency symbol. A num ric shift lock function is provided at bottom left, keying this will alternately set and release the numeric lock in the machine. Setting the numeric lock will release the capitals lock if set. With the numeric lock set, lower case alphabetics are unavailable, the numeric case is available without actuating the numeric shift key, the upper alphabetic case is obtained by actuating the upper case shift key in the same way as from lower case, and the control case is obtained by actuating both shift keys in the same way as from lower case. The required actuation may as described previously be either to press or to release the shift key, depending on whether the user wishes to rest the heels of his hand on the keyboard for most of the time.

Figs 15 and 16 show two preferred arrangements for the numeric case, having the digits 1 to 9 arranged in accordance with Marsan's observation, a 0 placed after 9 as in the conventional QWERTY keyboard, and an additional 0 placed before the 1, for operation by the same thumb as works the 1. One space cell is lost, but two remain. In these schemes, zero both precedes and follows the digits 1 to 9. Multiple zeros may be signalled with a single keystroke, the thumb operating the 0 positioned before the 1, and one or more fingers of the same hand indicating the required numb r of

z roes, dep nding on th finger k y or keys pressed. The remaining details may be as in Fig 14.

Fig 17 shows a proposed matrix for the control case. The null state of the keyboard with no finger or thumb key pressed is assigned to the same cell of the matrix as on the alphabetic and numeric cases for visual consistency and physical relationship with the thumbs. It is surrounded by eight cursor movement cells. The left hand home thumb key moves the cursor down, the left hand thumb key adjacent to the home key moves the cursor up. The right hand home thumb key moves the cursor to the right, the right hand thumb key adjacent to the home key moves the cursor to the left. Pressing one of these thumb keys of each hand moves the cursor at an angle.

Repeated vertical movement may be induced by pressing a left hand thumb key and one or more left hand home finger keys together, the frequency of repetition and therefore the speed of vertical movement depending on the finger key or keys pressed. Repeated horizontal movement may be induced by pressing a right hand thumb key and one or more right hand home finger keys together, the frequency of repetition and therefore the speed of horizontal movement depending on the finger key or keys pressed. Repeat d movement at an angle may be induced by pr ssing on thumb key of each hand and one

or more fing r k ys of each hand. The v rtical sp ed will depend on the left hand finger keys pressed and the horizontal speed will depend on the right hand finger keys pressed, so that movement at any angle may be achieved. A required cursor movement may be made rapidly at first and in an approximate direction, the speed being reduced and the direction corrected as the required final position is approached. The keyboard cursor control functions thus simulate the natural action of the hand when making any movement, such as positioning a mouse or puck. Figure 17 also shows in the leftmost column the "Run" function, the "Home", "Tab Backward" and "Newline" cursor control functions and the "Shift Reverse" function, in the second column from the left the "Normal Sound" function, in the third column the "Warning Sound" function, in the fifth column the "Tab Forward" and the "End of Text" cursor control functions, and at the bottom right the "Help" function as previously described. The "Run" function, variously titled Do, Enter, Execute or Run on conventional computer keyboards, initiates a predefined computer action, for example to read and process a screen of input data. The location of this function, obtained by extending both thumbs from their usual position, minimises the risk of accidentally keying the function and initiating an undesired computer action. Repeated newlines may be induced with th left hand finger keys

as for the ight basic cursor moves. The "Shift Reverse" function operates the machine switch which reverses the action of the shift keys, enabling the user to rest his hands on the keyboard when keying the lower case alphabet or to hold them up as he prefers. The location of this function corresponds to those of the Shift Lock functions on the capital and numeric matrices. The "Normal Sound" function operates the machine switch which turns on and off the aural feedback from a correct keystroke, the "Warning Sound" function operates the machine switch which turns on and off the aural feedback from an incorrect keystroke such as signalling one of the five consonants allocated to the right hand alone by a combination keystroke, or any key or combination of keys for which no decode is provided.

The eight basic cursor movement cells may be shifted by additional coding to enable the information plane to be moved relative to the physical screen. In a preferred form, the shift is effected by pressing the extended little finger key in addition to one or more thumb keys of a hand. The index finger at least will still be available to effect repeated movement.

The above described forms of the invention are appropriate for work which can be done effectively with digital input of positional data. For work r quiring

analogue input of positional data, th abov described keyboards for digital data entry may be combined with analogue devices for generating rate or displacement data. The analogue device may be of any known form such as a set of four buttons corresponding to the four directions of movement, which cause movement at a speed depending on the force with which they are pressed, a swash plate which can be tilted in any direction and causes movement in a corresponding direction on the screen at a speed depending on the force applied to tilt it, a control column or joy-stick which can be moved in any direction and causes movement in a corresponding direction on the screen at a speed depending on the displacement of the column, a tracker ball which can be rotated in any direction and causes movement in a corresponding direction on the screen with a displacement proportional to the rotation of the ball, or a mouse or puck which can be moved in any direction on a plane surface and causes movement in a corresponding direction on the screen with a displacement depending on the displacement of the mouse or puck.

In one form of the invention, a set of four buttons, swash-plate, joystick, tracker ball or other analogue device is located centrally on the keyboard. In other forms, th digital keyboard or part thereof is built

into the analogue device or part ther of; for example the whole keyboard may move bodily on a support surface, acting as a mouse. Digital signals may be used to enable or disable the analogue input and the physical movement of the whole keyboard.

In a "reduced" form of the invention, the alphabetic matrices may have the space character allocated to a right hand home key pressed alone, apart from the shift keys. The keyboard need only have 16 keys, and the positioning of the home thumb key and adjacent thumb key of each hand substantially at right angles which is desirable when the space character is allocated to an extended thumb key is not required. Figure 18 shows an alphabetic matrix having the space character and four high frequency consonants allocated to right hand single key presses. The vowels, remaining consonants, punctuation marks etc. are positioned as before. Figures 19 and 20 show numeric and control matrices for a 16-key keyboard. Further reductions are possible. Figure 21 shows an alphabetic matrix requiring only a 12-key keyboard, including the shift keys. Forms with 16 or fewer keys, located substantially in one plane, may be preferred to reduce the size and cost of the keyboard. The average number of keys pressed per character is increased however, and the work is poorly distribut d across th hands.

In "enhanced" forms of the invention, the keyboard may be provided with additional keys or key actions. Two rows of finger keys may be provided as shown in Fig 22 so that the index, middle and ring fingers operate two keys each by a short and direct reach forward and backward, without any lateral movement of these fingers such as causes the difficulty of learning the conventional QWERTY keyboard. The little fingers may be similarly provided with two keys for the home positions and two keys for the extended positions. The additional row of keys 4AL-8AL, 4AR-8AR for each hand may be placed above or below the main row. The additional keys may be operated instead of or in addition to corresponding keys of the main row. Alternatively, there may be only a single row of keytops for each hand, each keytop actuating two keyswitches by distinct motions such as a press against a light spring followed by a press against a stronger spring, or a press for one action and a rocking or wiping motion for the other action. The secondary signal may be given instead of or in addition to the primary signal, being distinct in either case. Similarly the home thumb key of each hand may be duplicated or provided with two distinct motions, as may the non-home thumb keys. Alternatively, the non-home thumb keys adjacent to respective home thumb keys in the main key row may be used as the duplicates of the home

keys, and the space character and zero which they produce in the 18-key form of keyboard transferred to the other non-home thumb keys nearest the midline of the keyboard. This option is shown in Fig 22. In these keyboards, the 18 keys corresponding to the 18-key form of the keyboard function as previously described. The additional 12 keys or key actions function similarly, so that in the alphabetic shifts left hand keys signal the vowels, right hand keys signal the common consonants, and combinations of one left hand and one right hand key signal the remaining consonants. Punctuation, numerics and so on may also be signalled on the additional keys in the same way as on the main keys. If the additional keys are used, the finger key or keys which signal a given character in the additional row are directly in line with the keys which signal that character in the main row, and the additional thumb key is similarly reached with an easy move from the home thumb key of the main row. If one keytop with two motions is used, the same keytops are used to signal a given character with either the main or the additional keyswitches. In all cases, the selected character when keyed on the additional row or with the additional motion will automatically be accompanied by a space character.

Instead of 10 or 12 additional keys or key actions, the k yboard may b provided with on or more elongate k ys

resembling the space bar of a conventional QWERTY keyboard, placed near to the main key row so that a digit may operate a key of the main row and an elongate key in the same action, causing the selected character to be accompanied by a space character. The elongate key or keys may be placed above or below the main row of keys and may extend along all or part of it. Fig 23 shows a keyboard having 18 keys, comprising for each hand two thumb keys 2L, 3L, 2R, 3R, five finger keys 4L-8L, 4R-8R, one elongate key 9L, 9R extending over the finger keys, and one heel key Z. The four shifts are selected by the heel keys. Letters, punctuation marks, numbers and other characters are selected by the home thumb keys and the finger keys as previously described. The same characters accompanied by the space character are selected by thumbs and/or fingers with essentially the same encoding, the thumbs pressing the non-home thumb keys and the fingers pressing the finger keys together with the elongate space keys. Space as a single character is signalled by pressing a space bar alone. Immediate repeat space may be obtained by pressing simultaneously the non-home thumb key and the elongate key of one hand, together with finger keys of the same hand to indicate the frequency of repetition. In the control shift, cursor movement is effected as described previously using the home and non-home thumb keys to control direction and the finger keys to control

speed. Th 'Run' function may be obtained by pr ssing simultaneously both heel keys and both elongate keys but no other keys.

With "enchanced" forms of the invention in which the signal decoding system is arranged to produce the selected character followed by a space character, the additional row or motion or the elongate key may be used for the last letter of a word, the last digit of a number, or a punctuation mark, to signal the space which follows it without a separate keystroke. With "enchanced" forms in which the signal decoding system is arranged to produce a space character followed by the selected character, the additional row or motion or the elongate key may be used for the first letter of a word or the first digit of a number to signal the space which precedes it without a separate keystroke. The latter arrangement may be psychologically preferable as the requirement for a space character comes first and may more effectively stimulate the use of the additional row or motion or the elongate key. It also accords better with practice in ordinary cursive handwriting, in which space is left before a word rather than after it. This arrangement also has the mechanical advantage that it may not be necessary to provide a duplicate key or second motion for the non-home little finger keys, as comma and period are not usually preceded by a space.

If exceptionally one is, a space may be signalled separately. Other punctuation marks such as quote marks or dashes may be preceded by a space, but these are signalled by combination keypresses of a little finger of one hand a digit of the other hand other than its little finger, and the space requirement may be signalled by this other digit actuating the additional row or motion or elongate key.

With all these "enchanced" forms of the invention, the work of the thumbs is halved, the number of keystrokes for a given text reduced by nearly 25% and the overall speed in terms of words per minute correspondingly increased. The average number of keys pressed per character including space is only 0.89, compared with 1.00 for the QWERTY, Dvorak or Maltron keyboards, 1.14 for the 18 - key form of the invention, and 1.82 for the Microwriter. Since the encoding is almost identical to that for the basic mode of operation, the additional learning required to achieve this benefit is small.

The basic signal detection requirement for any chord keyboard is to detect keystrokes comprising one, two or more digit key presses. Since the user is unlikely to depress two or more keys exactly together or release them exactly together, th signal det ction system must capture as a group all key presses signalled betw n two

successive null states of the k yboard with no digit key pressed. The determination of the code signalled must be made at the end of the keystroke when all the component key presses are known. In user terms, the desired character appears on the screen, or machine function executes, when he releases the keys, not when he presses them as with a conventional keyboard. It follows that a chord keyboard cannot provide "roll-over", the ability of a conventional computer keyboard to detect overlapping single keystrokes and interpret them as successive signals. The user must therefore strike the keys cleanly, as with a manual typewriter. With a keyboard requiring no large reaches, and but slight key actuating force and displacement, clean fingering should not be difficult.

The characters to be detected may include single letters, numbers, punctuation marks and other special symbols, diphthongs, accents overcoded on a letter within one keystroke, and accents coded as separate keystrokes. Multiple zeroes may be signalled with a single keystroke. There may be a signal requiring the character to be accompanied by a space. The machine functions to be detected may include Run, Help and cursor movement functions. An auto-repeat function may be provided, a keystroke held for more than a certain time being decoded before the release of the keys, it

being assum d that th user has stablish d his desired combination of key presses, and the character or machine function signalled being emitted repeatedly at a certain frequency until the keys are released. The proposed immediate repeat variable speed cursor movement, information plane movement and space encodings require the detection of particular signals as soon as they are established in a keystroke. The fully formed signals are unique in the encoding scheme as are all the proposed codes, but ambiguities will exist in some cases while the combination of key presses is being established. The Newline function and the four diagonal cursor movement functions require a combination of two thumb keys and one or more finger keys. Since the thumb keys will not in general be pressed at exactly the same moment, signals requiring immediate horizontal or vertical cursor movement will exist briefly, and could cause undesirable effects. There are no codes in the proposed coding scheme other than immediate action codes which when incomplete equate to an immediate action code, and incomplete signals not recognised as requiring immediate action are no problem. Siebel (1972) quotes Klemmer as finding that users can press multiple keys within 30 milliseconds. Conrad and Longman (1965) allowed 50 ms and obtain a 1% error rate with trainee operators. It is proposed therefore that the signal detection syst m shall impose a delay of the order of

50-100 ms t almost eliminate un xpect d cursor movement. This delay is still much shorter than th normal auto-repeat delay of some 500 ms, necessary to distinguish for any character or machine function the intent to repeat from a slow and indecisive keying intended as a single character or machine function, and the movement obtainable with the "immediate" function is also several times faster.

An invalid keystroke may usefully cause the emission of a space,so that the error may be corrected by overwriting or deleting rather than by inserting. The error may additionally be signalled by highlighting or by the emission of a sound. Sound effects resembling key clicks may be desired when valid keystrokes are detected, at least during the initial learning period. Two distinctive sounds may be emitted to indicate single key strokes and chord keystrokes. These sounds may be a single note and a chord.

The implementation of these signal detection requirements using a dedicated microprocessor is a matter of known art, and is outlined here solely for the convenience of the constructor. In Figure 24, K1 to K18 represent the eighteen keys of one form of the keyboard. L1 and L2 are the LEDs indicating which shift is in effect, and S is a sound generator. I is an input

port or ports of at least 18 bits, O is an output port or ports having at least 2 bits to drive the LEDs and as many more as are required to signal pitch and duration to the sound generator. Lines B represent the internal bus structure of the microcomputer, MPU is a microprocessor, ROM a read only memory, RAM a read/write memory, and P an output port sending data to the host computer HC or other information processing device. I, O and P may be combined in the form of one or more Programmable Interface Adaptors. In small personal computers, MPU and HC may be the same processor, and P is then not required. ROM contains a keyboard polling program and code conversion tables, and may usefully be of the plug-in variety so that the keyboard may be readily adapted to different character sets or command codes. RAM will contain transient data. "For "enhanced" forms of the invention, the input port I may have up to 30 bits and all decoding may be performed by software; alternatively the signals from the additional key or key motions may be diode encoded onto the lines from the main keys or key motions and onto an additional line conveying the space requirement. The form of keyboard with elongate keys will signal directly onto this additional line".

The program stored in ROM and executed by MPU is described below and with ref rence to th outline

fl wcharts Figs 25-28 and Table 5. The program comprises four blocks, which respectively determine the shift in effect, acquite the data from a digit keystroke, and output in the immediate repeat and deferred output modes. At start-up, MPU begins executing Block 1, Fig 25. At 101 the program reads port I to obtain the heel key data, then 102 if the shift reverse flag is set, the heel signals are reversed. If lower case alphabetic is signalled and the shift lock is set to upper case or numeric the lock overrides the input signal. A code indicating the shift in effect is stored, and data output to port O to illuminate L1 for upper case, L2 for numeric case, and both for control case. At 103 the program reads port I again to obtain the digit key data, and 104 the block repeats until a digit key is pressed, when control passes to Block 2.

Block 2, Fig 26, begins by 201 zeroing an accumulator, then 202 writes the latest digit key data into the accumulator with a logical AND operation. Until one of the exit conditions is satisfied, the block then repeats, 205 reading digit key data and 202 ANDing it into the accumulator, which thus builds a record of all digit keys pressed during the keystroke from the moment the first digit key is pressed to the moment that one of the conditions for nding the loop is detected. The

loop ends 203 if one of the key combinations indicating an immediate repeat requirement is detected, control then passing to Block 3, 204 if the loop count limit is reached, corresponding to the end of a suitable delay time, control then passing to Block 4 with 207 the auto-repeat flag set, or 206 if all digit keys have been released, control then passing to Block 4 with 208 the auto-repeat flag cleared. The conditions for immediate repeat are given in Table 5, which is a truth table. The third line for example asserts that one of the conditions for immediate repeat is that in the lower or upper case alphabetic shifts, the left hand and the right hand non-home thumb keys adjacent to respective home thumb keys are pressed, together with at least one left hand home finger key, irrespective of whether any right hand home finger keys are also pressed.

Block 3, Fig 27, is invoked when an immediate repeat condition has been detected. It begins 301 by zeroing counts for the vertical and horizontal movements, then 302 delays for some 50 milliseconds to allow for ragged key depression and 303 reads the digit keys again to obtain a stable reading. It then 304 decodes the thumb keys according to the shift in effect to identify repeat cursor movement, Newline or Space. For cursor movement this reading gives the quadrant of the movement, that is th directions of the vertical and horizontal

components of the movement. The decoding is performed by scanning the digit key data to identify for each hand that one of the keys pressed which lies nearest the middle of the keyboard, and deriving row and column arguments for a table lookup. If no key is pressed by one hand, then row or column 3 is assumed, in conformity with the matrix of Fig 5. Depending on the shift code stored by Block 1, one of four decode tables is then accessed. The entries in this table are ASCII codes for characters, and codes for the various commands, both those executed by the keyboard processor MPU and its program, and those sent to the host computer HC for it to execute. One of the local commands is a reject code, placed in all cells of the table which do not correspond to valid keystrokes. For cursor movement the program 305 scans the left hand home finger key data to identify that one of the keys pressed which lies furthest from the midline of the keyboard, and 306 adds to the vertical movement count 1 for the index finger through 4 for the little finger, and similarly with the right hand finger data for the horizontal movement. For Newline only the left hand data is scanned and for Space only the right hand data is scanned. When 307 a count reaches a set limit, 308 a vertical cursor move, horizontal cursor move, newline or space code is output to port P and 309 the count is zeroed. Thus the local command for cursor movement at an angle r ach s HC as a

s ries of vertical and horizontal moves. If with thumb keys denoting cursor movement the left hand non-home little finger key is pressed, then the vertical move is output to HC as a vertical information plane move rather than a cursor move, and similarly with the right hand non-home little finger key for the horizontal move. At 310 the program delays to give an appropriate overall cycle time, then 311 reads the digit keys again to obtain new speed information from the finger keys and 312 repeats the speed decoding and output operation until all digit keys are released, the directional information established at 304 remaining unaltered for the duration of the keystroke. At the end of the keystroke control reverts to Block 1.

If no immediate repeat requirement is detected, Block 4, Fig 28, is invoked at the end of the auto-repeat delay time, or if all digit keys are released before the end of the auto-repeat delay time. It begins 401 by scanning the digit key data as in Block 3 to identify the keys pressed nearest the midline of the keyboard and performing the table lookup. If 402 the table entry is the reject code then 403 data is sent to port O to cause the sound generator S to emit a warning sound, provided that the warning sound flag is set, and 404 a space character is output to port P for th us of HC, so making corr ctions asi r. If 405 the table entry is a

local command other than th reject code, then 406 data is sent to port P to cause S to emit a 'normal keystroke' sound, provided that the normal sound flag is set, and 407 the local command is executed. This command may set or clear the warning sound flag, the normal sound flag, the shift reverse flag, or the shift lock code. It is executed once only to avoid confusion, even though auto-repeat has been forced by the keyboard operator. If the table entry is not a local command, then 408 further decoding may be undertaken. In the alphabetic shifts, specific tests may be performed for bit patterns representing diphthongs or overcoded accents, and if found the output string extended appropriately. In the numeric shift, if zero has been keyed with the right thumb, the right hand home finger key data is scanned to identify that one of the keys pressed which lies furthermost from the midline of the keyboard, and the output string extended to 2, 3, 4 or 5 zeroes as required. In the control shift, if the thumb data indicates a vertical cursor move and the left hand non-home little finger key has been pressed, an information plane move is coded instead of a cursor move, and similarly for a horizontal move if the right hand non-home little finger key has been pressed. Then 409 the 'normal keystroke' sound is emitted as before, and 410 the output string is sent to port P character by character. At 411 the auto-repeat flag is tested and if

clear th block ends. If set, th n 412 a delay occurs to give an appropriate auto-repeat frequency, and then 413 the digit keys are read again and 414 while any digit keys are pressed the cycle of 'normal sound' and string output repeats at the set frequency. The output string remains that determined by steps 401 and 408 even if some digits are then added to or taken away from the keypress. When all digit keys are released the auto-repetition ceases. When the block ends at 404, 407 or 414, control reverts to Block 1.

In the program as described, all codes sent to the host computer may auto-repeat. It may alternatively be arranged that some codes such as Help and Execute are sent once only to obviate undesirable action by the host computer.

The program required by the "enhanced" forms of the invention is substantially identical to that described. At the end of the keystroke accumulation process Block 2 the bit pattern is tested for use of the additional keys or key motions. If used a flag is set to indicate that a space must be output, then the additional bits are ANDed with the corresponding bits of the data from the main key row or key motions and the decode processing proceeds as described. At the output stage 410 the sel cted character is output, preceded or followed by a

space character. In th cas of the k yboard with elongate space bars, the space flag is set if either space bar or either non-home thumb key is pressed. The truth table of Table 5 will also differ slightly.

CLAIMS

1. A keyboard, comprising a plurality of keys arranged in first and second groups for operation by the digits of respective hands of an operator, and means for decoding operation of the keys to provide signals representative of characters, characterised in that each group of keys comprises or includes five home keys (1L, 4L-7L; 1R, 4R-7R) arranged in a first single continuous row for respective digits of the hand, and in that the decoding means (MPU) is arranged to produce a signal representative of each of the vowels upon operation of a respective single home key (1L, 4L-7L) of the first group and to produce a signal representative of each of at least some of the consonants upon simultaneous operation of a home key (1L, 4L-7) of the first group and a home key (1R, 4R-7R) of the second group.

2. A keyboard as claimed in claim 1, characterised in that the decoding means (MPU) is arranged to produce a signal representative of at least some of the consonants upon simultaneous operation of the home key (1L, 4L-7L) of the first group corresponding to the vowel preceding the respective consonant in alphabetical order and a home key (1R, 4R-7R) of the second group.

3. A k yboard as claimed in claim 1, or 2

charact ris d in that th first and second groups of keys are arranged to be operated by the left and right hands, respectively.

4. A keyboard as claimed in any one of the preceding claims, characterised in that the home keys (1L, 4L-7L) of the first group corresponding to the vowels a, e, i, o and u are arranged to be operated by the thumb and the index, middle, ring, and little finger, respectively.

5. A keyboard as claimed in claim 4, characterised in that the decoding means (MPU) is arranged to provide signals representing five characters selected from common consonants and other characters including space upon operation of respective single home keys (1R, 4R-7R) of the second group.

6. A keyboard as claimed in claim 5, characterised in that the decoding means (MPU) is arranged to produce a signal representative of each of the consonants other than selected consonants upon simultaneous operation of the key (1L, 4L-7L) of the first group corresponding to the alphabetically preceding vowel and the respective home key (1R, 4R-7R) of the second group corresponding to the relative position of the consonant with respect to the consonants other than the selected consonants following th vow l and taken in order from th thumb to

th little finger.

7. A keyboard as claimed in any one of the preceding claims, characterised in that the decoding means (MPU) is arranged to produce a signal representative of an accented letter upon simultaneous operation of the keyboard for selecting the non-accented letter and a further key (2R) or keys.

8. A keyboard as claimed in any one of the preceding claims, characterised in that at least one of the groups of keys includes a non-home key (2L, 2R) for operation by the thumb, and the decoding means (MPU) is arranged to produce a signal representative of a space in response to operation of the non-home thumb key (2L, 2R).

9. A keyboard as claimed in claim 8, characterised in that the decoding means (MPU) is arranged to produce signals representative of space repeatedly in response to simultaneous operation of the non-home thumb key (2L, 2R) and at least one finger key of the same group, the frequency of repetition depending on the at least one finger key operated.

10. A keyboard as claim d in any one of the preceding claims, characterised in that each of the first and

sec nd gr ups of keys includes a non-home key (2L, 2R) for operation by the thumb, and the decoding means (MPU) is arranged to produce a signal representative of a space in response to simultaneous operation of both the non-home thumb keys (2L, 2R).

11. A keyboard as claimed in claim 10, characterised in that the decoding means (MPU) is arranged to produce signals representative of space repeatedly in response to simultaneous operation of both the non-home keys (2L, 2R) and of at least one finger key, the frequency of repetition depending on the at least one finger key operated.

12. A keyboard as claimed in claim 1, in any one of the preceding claims, characterised in that each of the first and second groups of keys includes a non-home key for operation by the little finger (8L, 8R), and the decoding means (MPU) is arranged to produce signals representative of a period (full stop) and comma in response to operation of the respective non-home little finger keys (8L, 8R).

13. A keyboard as claimed in any oen of the preceding claims, characterised in that the keyboard includes at l ast one shift key (Z) arranged to be operated by the h l of the hand and the decoding means (MPU) is

arranged t p rform a shift function in response to operation of the at least one shift key (Z).

14. A keyboard as claimed in any one of claims 1 to 12, characterised in that the keyboard includes at least one shift key (Z) arranged to be operated by the heel of the hand and the decoding means (MPU) is arranged to perform a shift function in response to release of the at least one shift key (Z).

15. A keyboard as claimed in any one of the preceding claims, characterised in that the decoding means (MPU) is arranged to produce a signal representative of a numeric digit in response to operation of a respective home (1L, 4L-7L, 1R, 4R-7R) key when in numeric shift.

16. A keyboard as claimed in claim 15, characterised in that the decoding means (MPU) is arranged to produce a signal representative of zero upon operation of a non-home thumb key (2L, 2R) disposed adjacent to a home thumb key(1L, 1R).

17. A keyboard as claimed in claim 16, characterised in that the decoding means (MPU) is arranged to produce multiple signals representative of zero upon simultaneous operation of the non-home thumb key (2L, 2R) and at l ast one finger key of the sam group, the

number of zeroes produced d pending on the at least on finger key operated.

18. A keyboard as claimed in any one of the preceding claims, characterised in that the decoding means (MPU) is arranged to produce signals representative of cursor movement in response to operation of a home thumb key (1L, 1R) or an adjacent non-home thumb key (2L, 2R) when in control shift, the thumb keys (1L, 2L) of one hand signalling horizontal movement and the thumb keys (1R, 2R) of the other hand signalling vertical movement.

19. A keyboard as claimed in claim 18, characterised in that the decoding means (MPU) is arranged to produce signals representative of cursor movement repeatedly in response to simultaneous operation of a thumb key (1L, 2L, 1R, 2R) and at least one finger key of the same group, the frequency of repetition depending on the at least one finger key pressed.

20. A keyboard as claimed in claim 18, characterised in that the decoding means (MPU) is arranged to produce signals representative of cursor movement at an angle in response to simultaneous operation of one home thumb key (1L, 1R) or adjacent non-home thumb key (2L, 2R) of each group when in control shift, the thumb key (1L, 2L) op rat d in one group d termining the direction of the

horizontal component of the movem nt and the thumb key (1R, 2R) operated in the other group determining the direction of the vertical component of the movement.

21. A keyboard as claimed in claim 20, characterised in that the decoding means (MPU) is arranged to produce signals representative of cursor movement at an angle repeatedly in response to the simultaneous operation of a thumb key (1L, 1R, 2L, 2R) of each group and at least one finger key of each group, the thumb key and at least one finger key operated in one group determining the direction and speed, respectively, of the horizontal component of the movement and the thumb and at least one finger key operated in the other group determining the direction and speed, respectively, of the vertical component of the movement.

22. A keyboard as claimed in claim 18 to 21, characterised in that the decoding means (MPU) is arranged to produce a signal representative of the 'Run' function in response to the simultaneous operation of a further non-home thumb key (3L, 3R) of each group when in the control shift, the further non-home thumb keys being disposed at the ends of the rows of keys in each group remote from the home thumb keys (1L, 1R) for operation by the extended thumbs.

23. A k yboard as claimed in any one of th pr ceding claims, characterised in that the keyboard is shaped to fit the natural curve of the hands at rest with the fingers curved in a moderate arc and the wrists straight.

24. A keyboard as claimed in claim 23, characterised in that the general planes of the keys for each hand are tilted outwards in order to reduce the angle of forearm pronation.

25. A keyboard as claimed in claim 23 or 24, characterised in that the or at least one thumb key (1L, 1R) of each group is disposed at an angle to the general plane of the finger keys (4L-8L, 4R-8R) of the respective group for operation by adduction of the thumb towards the palm of the hand.

26. A keyboard as claimed in 23 or 24, characterised in that the home thumb key (1L, 1R) of each group is disposed substantially at right angles to the general plane of the finger keys (4L-8L, 4R-8R) of the respective group and non-home thumb keys (2L, 3L, 2R, 3R) of each group are disposed substantially parallel to the respective general plane, so that the home and adjacent non-home thumb keys (1L, 2L, 1R, 2R) may be operated from the same position of the thumb.

27. A keyboard as claimed in any one of the preceding claims, characterised in that each group of keys includes five additional keys (4AL-8AL, 4AR-8AR) arranged in a second single continuous row for operation by respective digits of the respective hand, and the decoding means (MPU) is arranged to produce in response to operation of at least one key of the first and second rows, including at least one key of the second row, a signal representative of the same characters as in response to corresponding keys all of the first row, preceded or followed by a signal representative of the space character.

28. A keyboard as claimed in any one of claims 1 to 26, characterised in that each group of keys includes at least one elongate key (9L, 9R) arranged to be operated by any of a plurality of digits of the respective hand, and the decoding means (MPU) is arranged to produce, in response to simultaneous operation of at least one key in the first rows of keys and at least one of the elongate keys (9L, 9R), a signal representative of the same character as in response to operation of the at least one key of the first rows only preceded or followed by a signal representative of the space character.

29. A keyboard as claimed in any one of claims 1 to 26, charact rised in that each of at least th home keys

(1L, 4L-7L, 1R, 4R-7R) of each group is provided with an additional distinct motion, and the decoding means (MPU) is arranged to produce, in response to the additional distinct motion of at least one of the home keys, a signal representative of the same character as in response to operation of the same key combination without the additional motion preceded or followed by a signal representative of the space character.

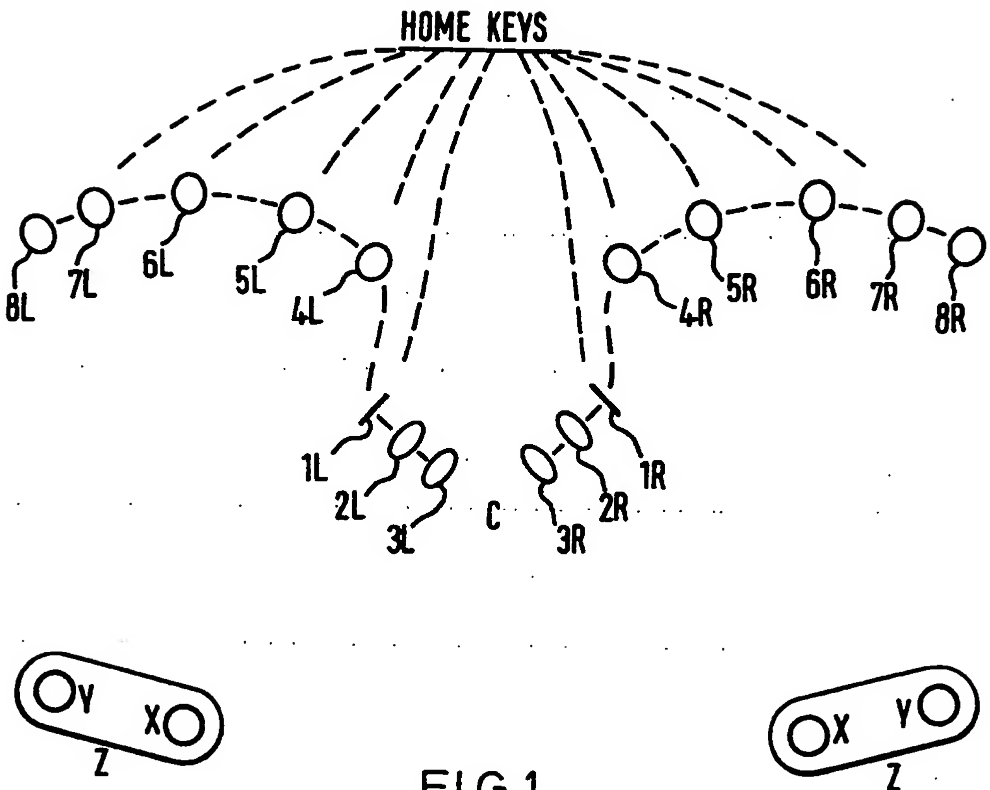

FIG.1.

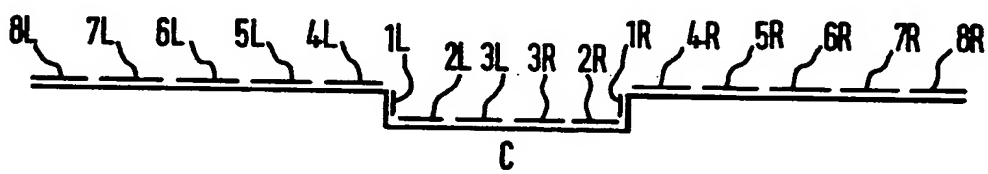

FIG.2.

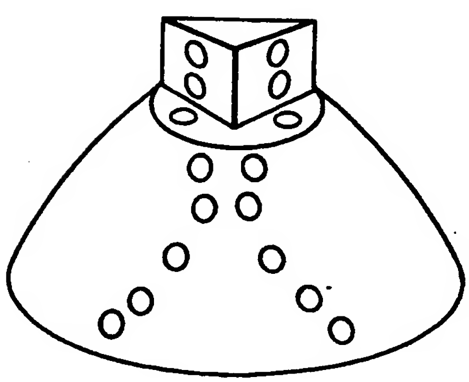

FIG.3.

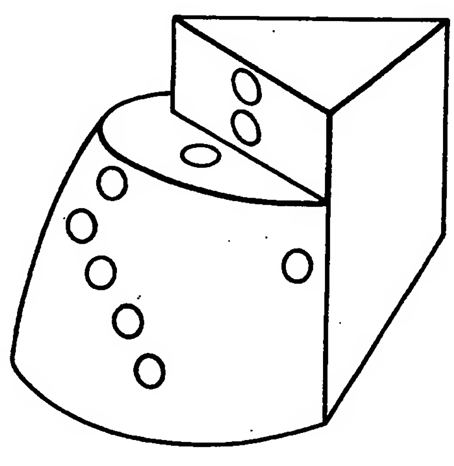

FIG.4.

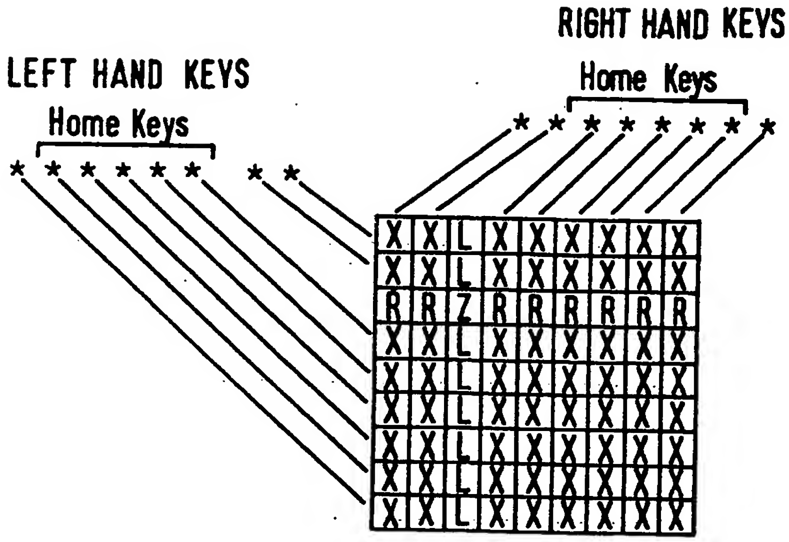

FIG.5.

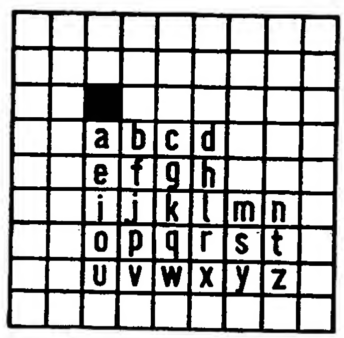

FIG.6.

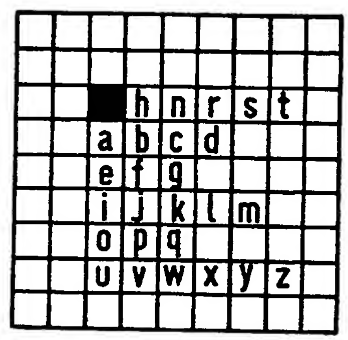

FIG.7.

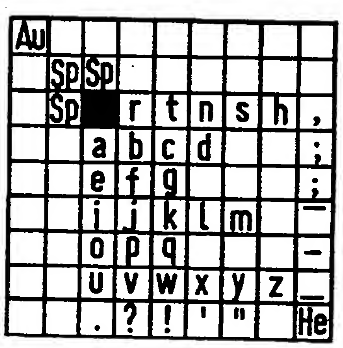

FIG 8

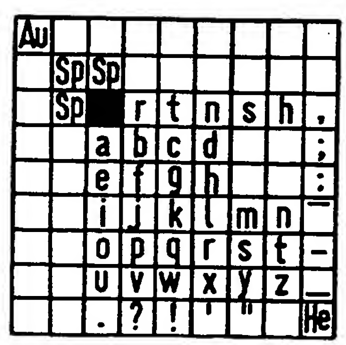

FIG.9.

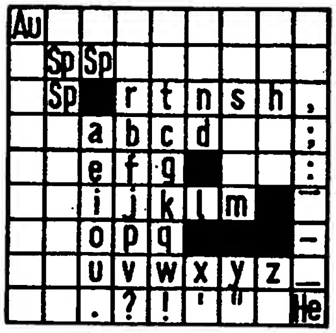

FIG.10.

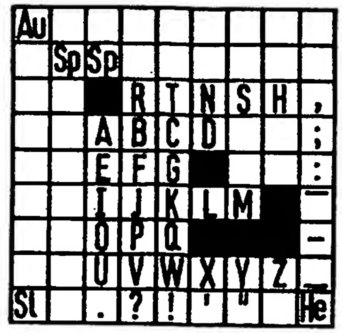

FIG.11.

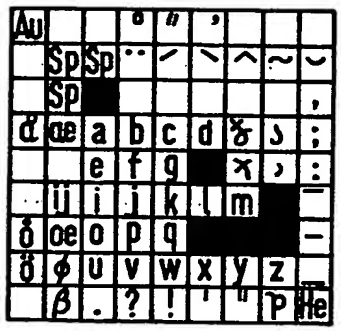

FIG.12.

		RIGHT HAND KEYS							
		Th	Th	Th	I	M	R	L	L
Vowel Accents	¨		*		*				
	´		*			*			
	`		*				*		
	^		*					*	
Accented Consonant	ç				*	*			

FIG.13.

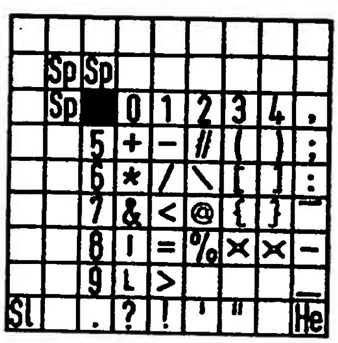

FIG.14.

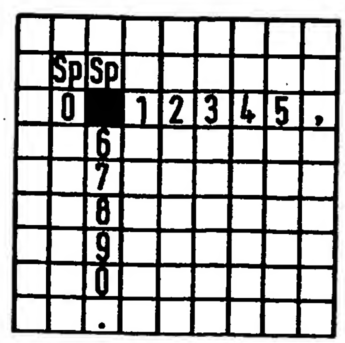

FIG.15.

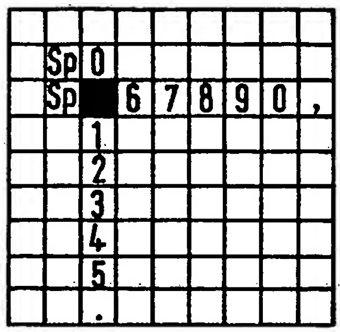

FIG.16.

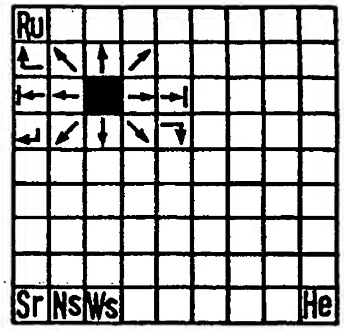

FIG.17.

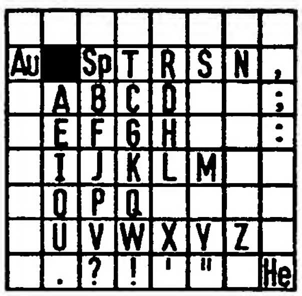

FIG.18.

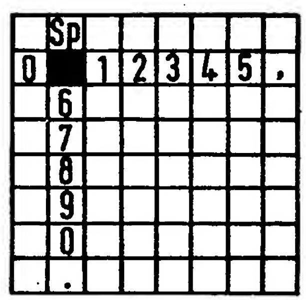

FIG.19.

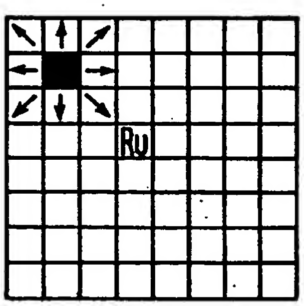

FIG.20.

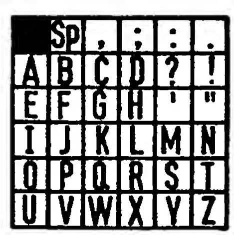

FIG.21.

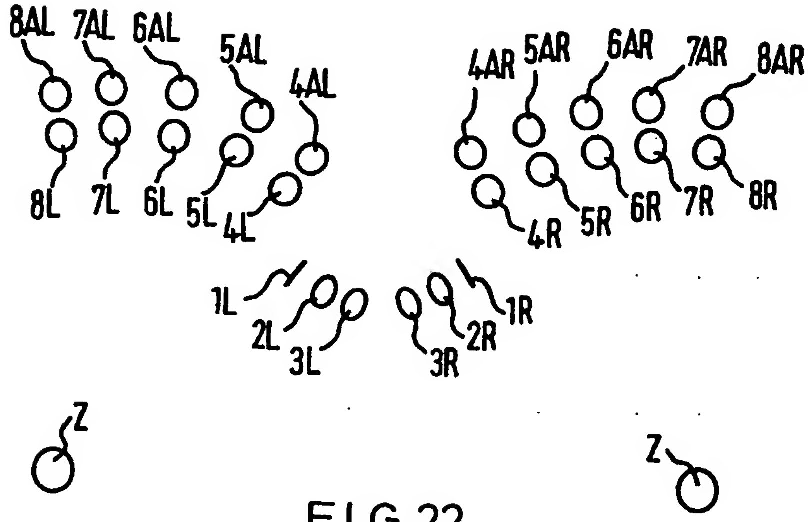

FIG.22.

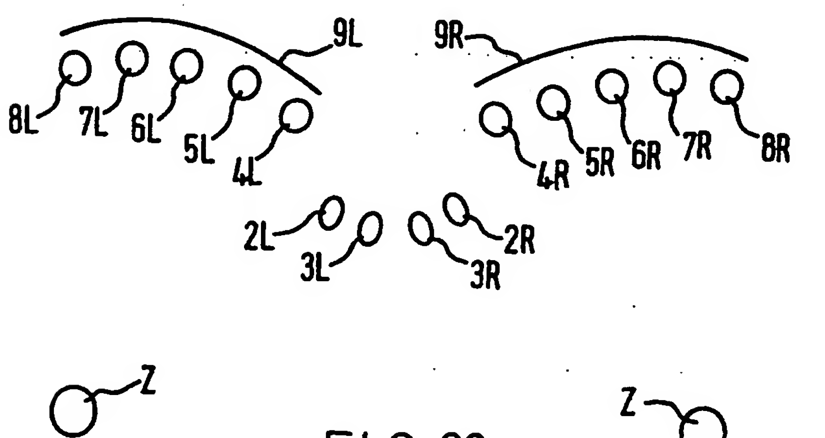

FIG.23.

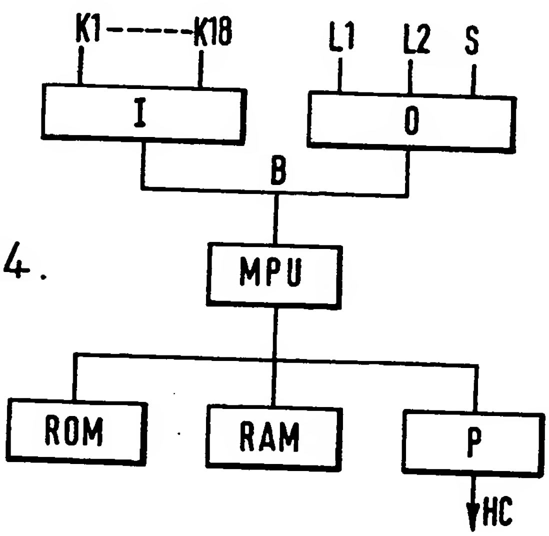

FIG.24.

0134160

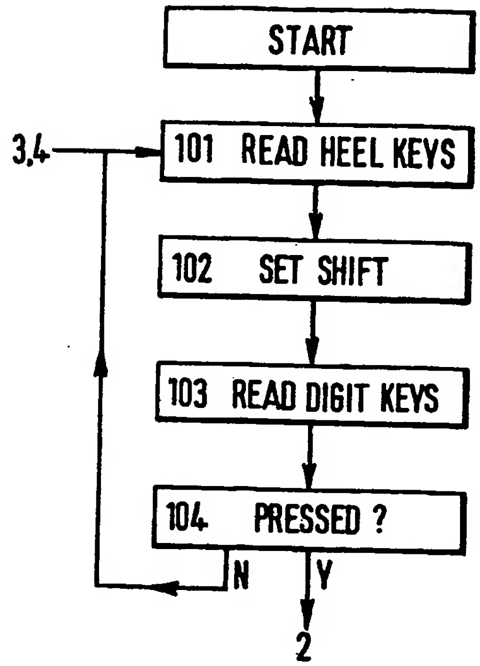

FIG.25.

BLOCK 1 — SHIFT

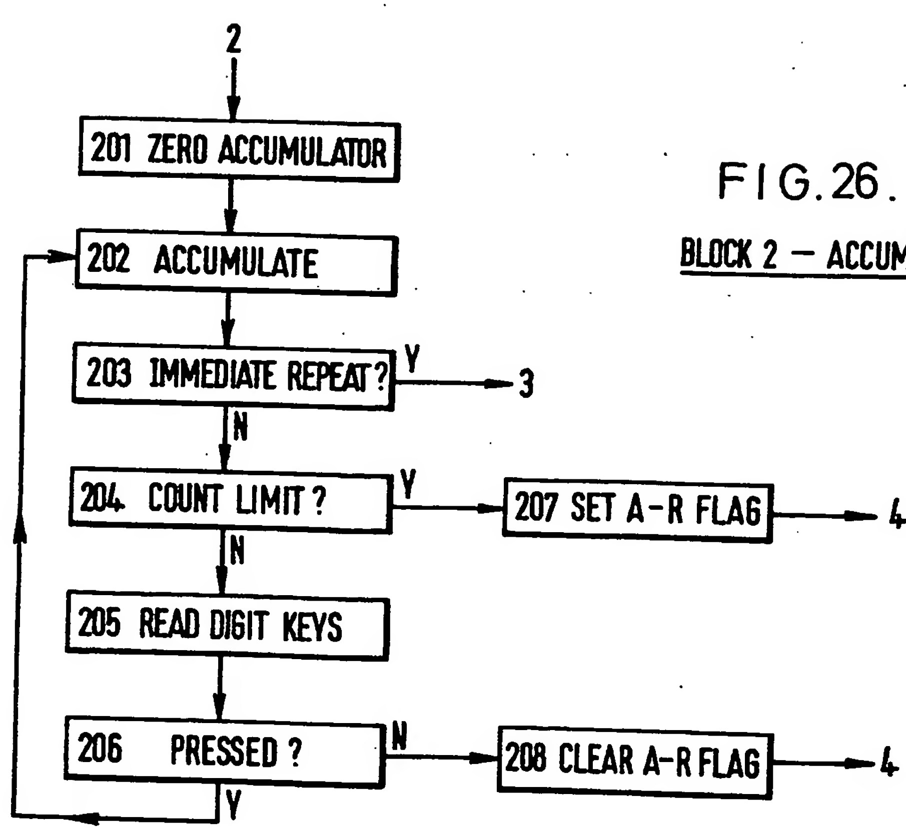

FIG.26.

BLOCK 2 — ACCUMULATE

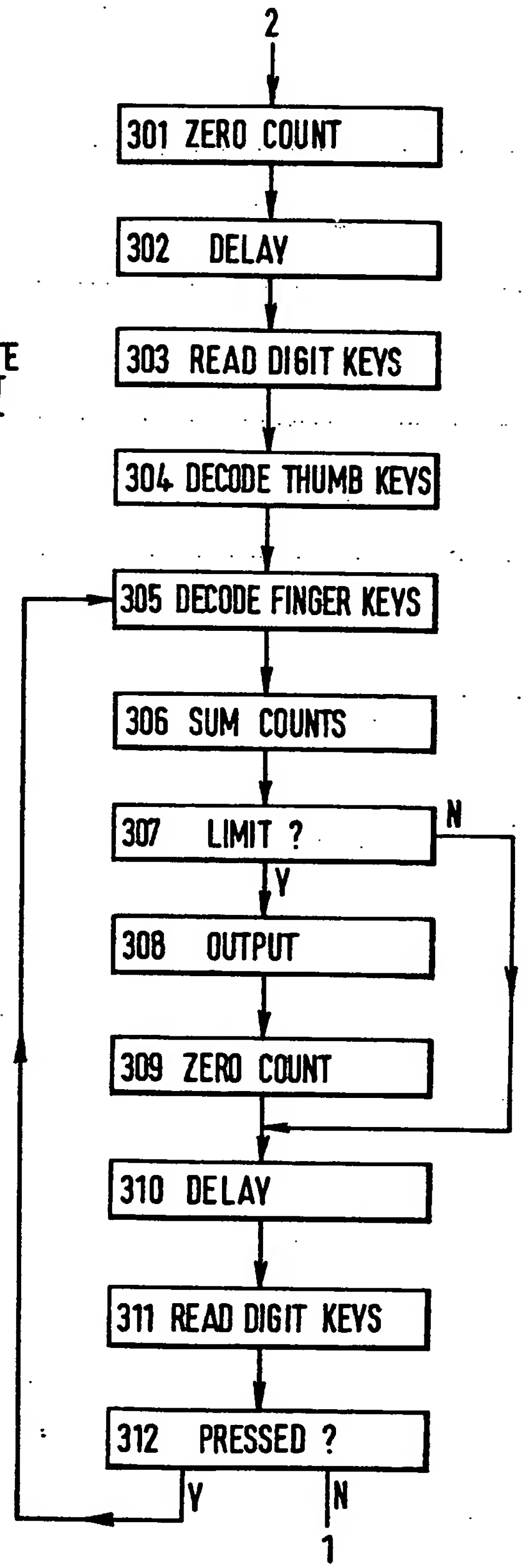

FIG. 27.

BLOCK 3 — IMMEDIATE REPEAT

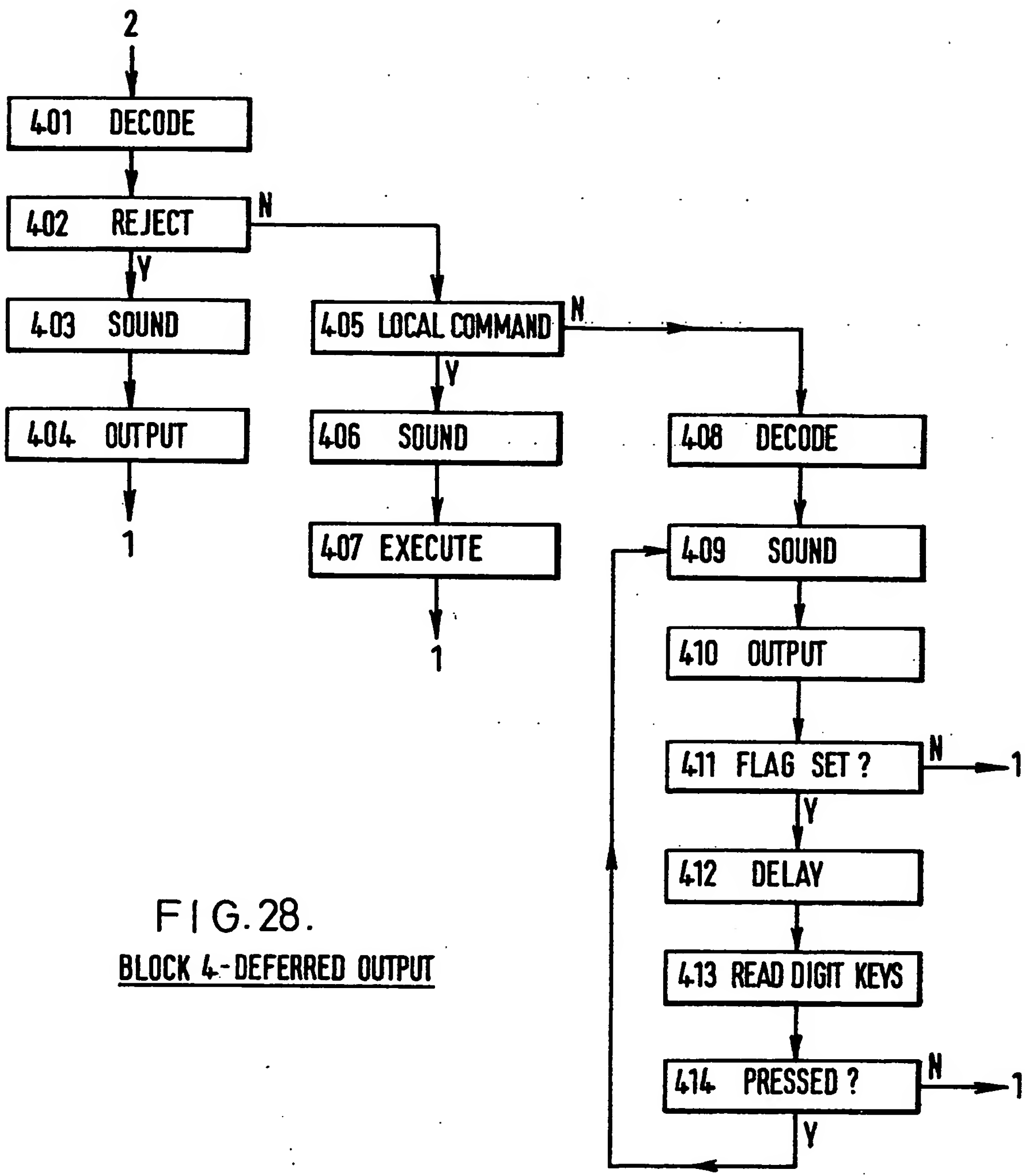

FIG. 28.

BLOCK 4-DEFERRED OUTPUT

Total	Little	Ring	Middle	Index	LEFT Thumb (Addn)	LEFT Thumb (Rotn)	RIGHT Thumb (Rotn)	RIGHT Thumb (Addn)	Index	Middle	Ring	Little	Total
56.9	7.8	6.8	9.3	11.6	10.2	11.2	13.5	7.8	11.9	9.5	7.1	7.3	57.1
											GRAND	TOTAL	114.0

TABLE .1.

	Total	Little	Ring	Middle	Index	LEFT Thumb (Addn)	LEFT Thumb (Rotn)	RIGHT Thumb (Rotn)	RIGHT Thumb (Addn)	Index	Middle	Ring	Little	Total
Invention	49.9	6.8	6.0	8.2	10.2	8.9	9.8	11.8	6.8	10.4	8.3	6.2	6.4	50.1
QWERTY	55.2	6.2	5.9	13.9	17.2	0.0	12.3	12.3	0.0	16.2	5.4	9.5	1.0	44.4
Dvorak	45.3	6.1	6.6	9.6	10.7	0.0	12.3	12.3	0.0	13.9	11.5	10.1	6.7	54.5
Strength	50	5	8	10	11	–	16	16	–	11	10	8	5	50
Speed	48	10	12	13	13	–	–	–	–	14	14	13	11	52

TABLE .2.

	English	French	German	Italian	Spanish
A	6.6	7.8	4.8	9.7	9.8
E	10.3	11.5	13.4	9.8	11.7
I	6.0	7.0	6.8	9.4	5.2
O	6.3	4.2	2.1	7.6	7.4
U	2.2	5.1	4.0	2.5	3.5
TOTAL VOWELS	31.4	35.6	31.1	39.0	37.6
TOP FIVE CONSONANTS	28.4	29.7	29.8	26.4	26.6
SUBTOTAL	59.8	65.3	60.9	65.4	64.2
REMAINING CONSONANTS AND PUNCTUATION	22.6	17.5	23.1	18.0	19.1
SPACE	17.6	17.2	16.0	16.6	16.7
TOTAL	100.0	100.0	100.0	100.0	100.0

TABLE.3.

I	1	2	3	4	5	6	7	8	9	0
II	0	1	2	3	4	5	6	7	8	9
III	8	6	4	2	0	1	3	5	7	9
IV	0	9	8	7	6	1	2	3	4	5
V	9	8	7	6	5	0	1	2	3	4

TABLE.4.

IMMEDIATE REPEAT TRUTH TABLE

SHIFT	LEFT				RIGHT			
	TH	TH	TH	FINGERS	TH	TH	TH	FINGERS
ALPHA	0	1	0	1	0	0	0	0
	0	0	0	0	0	1	0	1
	0	1	0	1	0	1	0	–
	0	1	0	–	0	1	0	1
NUM	0	0	0	0	0	1	0	1
CTRL	0	1	0	1	0	0	0	0
	0	1	0	1	0	1	0	–
	0	1	0	1	0	0	1	–
	0	0	1	1	0	0	0	0
	0	0	1	1	0	1	0	–
	0	0	1	1	0	0	1	–
	0	0	0	0	0	1	0	1
	0	1	0	–	0	1	0	1
	0	0	1	–	0	1	0	1
	0	0	0	0	0	0	1	1
	0	1	0	–	0	0	1	1
	0	0	1	–	0	0	1	1
	0	0	1	1	1	0	0	0

TABLE. 5.

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Summary

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